ANL-NEAMS-4

FY2012 Summary of Tasks Completed on PROTEUS-Thermal Work

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March 31, 2012

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DISCUSSION

PROTEUS is a suite of the neutronics codes, both old and new, that can be used within the SHARP codes [1] being developed under the NEAMS program. Discussion here is focused on updates and verification and validation activities of the SHARP neutronics code, DeCART [2], for application to thermal reactor analysis. As part of the development of SHARP tools, the different versions of the DeCART code created for PWR, BWR, and VHTR analysis [4-5] were integrated. Verification and validation tests for the integrated version were started, and the generation of cross section libraries based on the subgroup method [3] was revisited for the targeted reactor types.

The DeCART code has been reorganized in preparation for an efficient integration of the different versions for PWR, BWR, and VHTR analysis. In DeCART, the old-fashioned common blocks and header files have been replaced by advanced memory structures. However, the changing of variable names was minimized in order to limit problems with the code integration. Since the remaining stability problems of DeCART were mostly caused by the CMFD methodology and modules, significant work was performed to determine whether they could be replaced by more stable methods and routines.

The cross section library is a key element to obtain accurate solutions. Thus, the procedure for generating cross section libraries [6] was revisited to provide libraries tailored for the targeted reactor types. To improve accuracy in the cross section library, an attempt was made to replace the CENTRM code [6] by the MCNP Monte Carlo code as a tool obtaining reference resonance integrals. The use of the Monte Carlo code allows us to minimize problems or approximations that CENTRM introduces since the accuracy of the subgroup data is limited by that of the reference solutions. The use of MCNP requires an additional set of libraries without resonance cross sections so that reference calculations can be performed for a unit cell in which only one isotope of interest includes resonance cross sections, among the isotopes in the composition.

The OECD MHTGR-350 benchmark core [7] was simulated using DeCART as initial focus of the verification/validation efforts. Among the benchmark problems, Exercise 1 of Phase 1 is a steady-state benchmark case for the neutronics calculation for which block-wise cross sections were provided in 26 energy groups. This type of problem was designed for a homogenized geometry solver like DIF3D rather than the high-fidelity code DeCART. Instead of the homogenized block cross sections given in the benchmark, the VHTR-specific 238-group ENDF/B-VII.0 library of DeCART was directly used for preliminary calculations. Initial results showed that the multiplication factors of a fuel pin and a fuel block with or without a control rod hole were off by 6, -362, and -183 pcm Δk from comparable MCNP solutions, respectively. The 2-D and 3-D one-third core calculations were also conducted for the all-rods-out (ARO) and all-rods-in (ARI) configurations, producing reasonable results. Figure 1 illustrates the intermediate (1.5 eV – 17 keV) and thermal (below 1.5 eV) group flux distributions. As seen from VHTR cores with annular fuels, the intermediate group fluxes are relatively high in the fuel region, but the thermal group fluxes are higher in the inner and outer graphite reflector regions than in the fuel region.

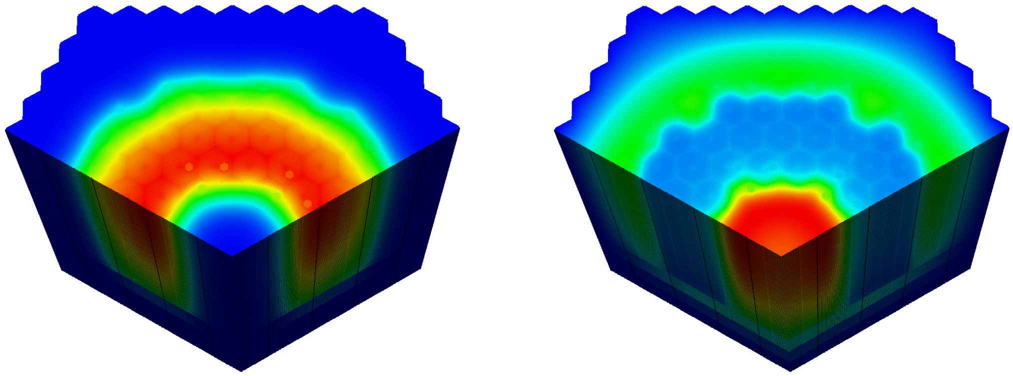

Figure 1. Flux Distributions of One-third Core of MHTGR-350 with ARO

To support the current project, a new three-year I-NERI collaboration involving ANL and KAERI was started in November 2011, focused on performing in-depth verification and validation of high-fidelity multi-physics simulation codes for LWR and VHTR. The work scope includes generating improved cross section libraries for the targeted reactor types, developing benchmark models for verification and validation of the neutronics code with or without thermo-fluid feedback, and performing detailed comparisons of predicted reactor parameters against both Monte Carlo solutions and experimental measurements.

The following list summarizes the work conducted so far for PROTEUS-Thermal Tasks:

- Unification of different versions of DeCART was initiated, and at the same time code modernization was conducted to make code unification efficient.
- Regeneration of cross section libraries was attempted for the targeted reactor types, and the procedure for generating cross section libraries was updated by replacing CENTRM with MCNP for reference resonance integrals.
- The MHTGR-350 benchmark core was simulated using DeCART with VHTR-specific 238-group ENDF/B-VII.0 library, and MCNP calculations were performed for comparison.
- Benchmark problems for PWR and BWR analysis were prepared for the DeCART verification/validation effort.

In the coming months, the work listed above will be completed. Cross section libraries will be generated with optimized group structures for specific reactor types. For code verification using the MHTGR-350 benchmark problem, block-wise homogenized cross sections will be used to satisfy the current benchmark specification and, if possible, pin-by-pin cross sections will be proposed for use in a high-fidelity code like DeCART. In addition, validation cases will be selected for each reactor type and simulated with DeCART. Systematic verification tests will be performed to compare global and local solutions of selected reactors between DeCART and MCNP.

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